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A brief summary of a three-year investigation of waveguides, passive components, active circuits and antennas for millimeter waves is presented. Research concentrated entirely on low loss, low cost and lightweight dielectrics that provide an alternate choice to metallic media which become lossy and expensive at millimeter wavelengths. The summary is supplemented by a complete listing of reports and journal publications resulting from the research.

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INVESTIGATION OF QUASI-OPTICAL INTEGRATED CIRCUITS AND ELECTROMAGNETIC SCATTERING AND RADIATION PROBLEMS

Final Report

for the period

1 March 1977 to 30 April 1980

Raj Mittra

July 1980

U. S. Army Research Office

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STATEMENT OF THE PROBLEM/SUMMARY

During the tenure of the grant in the last three years, we have been engaged in the investigation of waveguides, passive components, active circuits and antennas for millimeter waves. We have been concentrating entirely on low loss, low cost and lightweight dielectrics that provide an alternate choice to metallic media which become lossy and expensive at millimeter wavelengths.

We have investigated several different types of dielectric waveguides, e.g., the inverted strip and image guide, and have also studied various components derived from these waveguides. These structures have been investigated extensively both from the theoretical and experimental points of view. Two different approaches to analyzing dielectric waveguides have been developed. One of these is based on the mode matching technique which is applied in conjunction with the variational method. The second approach, developed more recently, employs the field expansion method as a first step, and is relatively more efficient as well as accurate. Extensive numerical results have been obtained using the field expansion method. These results have been compared against experimental measurements, and good agreement has been found. Comparison with results published elsewhere has revealed that the propagation constant predicted by the present technique agrees more closely with the experimental data than those derived using either the well-known effective dielectric constant of Toulios or the approximate methods of Goell and Marcatali, orginally derived for planar waveguides.

One of the vexing problems in an open waveguide is the unwanted radiation from bends or other discontinuities which are invariably present in such components as couplers and resonators. We have investigated this problem and have designed a shield which reduces the radiation loss by as much as 7 to 8 dB thus making the loss due to radiation virtually negligible.

The shielded dielectric guide becomes an oversized, and hence over-moded, waveguide when the shield completely encloses the dielectric guide. Such a multimode guide may find useful application at frequencies above 100 GHz. We have developed analytical tools for investigating such waveguides.

A number of dielectric antenna configurations for millimeter wave applications have been designed and studied both theoretically and experimentally. Uniform or tapered dielectric rods, operating as surface wave antennas, radiate primarily in the endfire direction. When discontinuities, such as metal strips, are introduced in these rods, the primary mode of radiation changes to leaky wave type. We have successfully predicted some of the radiation characteristics, e.g., the direction of the main beam and the beamwidth, on a theoretical basis and have verified these predictions experimentally.

In addition to passive structures we have designed a number of active circuits, e.g., oscillators and mixers. We have addressed the problem of configuring open cavity designs that are compatible with dielectric waveguides. To date, we have built oscillators which have successfully operated up to 60 GHz. However, the designs themselves should be useful to 94 GHz range.

PERSONNEL

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